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Computational Modelling and Simulation of Scaffolds for Bone Tissue Engineering

Authors: Haja-Sherief N. Musthafa, Jason Walker and Mariusz Domagala

Abstract: Three-dimensional porous scaffolds are substitutes for traditional bone grafts in bone tissue engineering (BTE) applications to restore and treat bone injuries and defects. The use of computational modelling is gaining momentum to predict the parameters involved in tissue healing and cell seeding procedures in perfusion bioreactors to reach the final goal of optimal bone tissue growth. Computational modelling based on finite element method (FEM) and computational fluid dynamics (CFD) are two standard methodologies utilised to investigate the equivalent mechanical properties of tissue scaffolds, as well as the flow characteristics inside the scaffolds, respectively. The success of a computational modelling simulation hinges on the selection of a relevant mathematical model with proper initial and boundary conditions. This review paper aims to provide insights to researchers regarding the selection of appropriate finite element (FE) models for different materials and CFD models for different flow regimes inside perfusion bioreactors. Thus, these FEM/CFD computational models may help to create efficient designs of scaffolds by predicting their structural properties and their haemodynamic responses prior to in vitro and in vivo tissue engineering (TE) applications.

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Investigation of the Failure Response of Masonry Walls Subjected to Blast Loading Using Nonlinear Finite Element Analysis

Authors: Sipho G. Thango, Georgios E. Stavroulakis and Georgios A. Drosopoulos

Abstract: A numerical investigation of masonry walls subjected to blast loads is presented in this article. A non-linear finite element model is proposed to describe the structural response of the walls. A unilateral contact–friction law is used in the interfaces of the masonry blocks to provide the discrete failure between the blocks. A continuum damage plasticity model is also used to account for the compressive and tensile failure of the blocks. The main goal of this article is to investigate the different collapse mechanisms that arise as an effect of the blast load parameters and the static load of the wall. Parametric studies are conducted to evaluate the effect of the blast source–wall (standoff) distance and the blast weight on the structural response of the system. It is shown that the traditional in-plane diagonal cracking failure mode may still dominate when a blast action is present, depending on the considered standoff distance and the blast weight when in-plane static loading is also applied to the wall. It is also highlighted that the presence of an opening in the wall may significantly reduce the effect of the blasting action.

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A Numerical Approach for Developing a Bearing-Bypass Design Criterion for Sizing Bolted Joints

Author: Dimitrios G. Stamatelos

Abstract: Bolted joints are widely used in composite aircraft structures, for their assembly. The appropriate bolted joint configuration (hole/bolt diameter, pitch, etc.) is carefully selected during the detail design phase, where high fidelity numerical models are required with substantial computational cost and time. This work presents a design criterion, which allows the selection of the bolted joint configuration during the preliminary design phase with less computational time. The developed design criterion is based on a fully parametric finite element (FE) model, built in ANSYS V19 (Canonsburg, PA, USA), of a bolted joint with progressive damage modelling (PDM) capabilities, so that the failure of the joint can be predicted. From the numerical analyses, the bearing load and the load that bypasses the hole are calculated, up to failure, for a variety of joint configurations and loading conditions. The results of each analysis are used for plotting the failure envelope for the investigated bolted-joint configuration. Consequently, a design criterion is generated for the bolted joint. The availability of these failure envelopes, as design criterion, permit the appropriate selection of the bolted-joint configuration in an earlier design phase saving valuable time and computational cost.

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Taylor Polynomials in a High Arithmetic Precision as Universal Approximators

Author: Nikolaos Bakas

Abstract: Function approximation is a fundamental process in a variety of problems in computational mechanics, structural engineering, as well as other domains that require the precise approximation of a phenomenon with an analytic function. This work demonstrates a unified approach to these techniques, utilizing partial sums of the Taylor series in a high arithmetic precision. In particular, the proposed approach is capable of interpolation, extrapolation, numerical differentiation, numerical integration, solution of ordinary and partial differential equations, and system identification. The method employs Taylor polynomials and hundreds of digits in the computations to obtain precise results. Interestingly, some well-known problems are found to arise in the calculation accuracy and not methodological inefficiencies, as would be expected. In particular, the approximation errors are precisely predictable, the Runge phenomenon is eliminated, and the extrapolation extent may a priory be anticipated. The attained polynomials offer a precise representation of the unknown system as well as its radius of convergence, which provides a rigorous estimation of the prediction ability. The approximation errors are comprehensively analyzed for a variety of calculation digits and test problems and can be reproduced by the provided computer code.

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Topology Optimization and Efficiency Evaluation of Short-Fiber-Reinforced Composite Structures Considering Anisotropy

Authors: Evgenii Kurkin, Oscar Ulises Espinosa Barcenas, Evgenii Kishov and Oleg Lukyanov

Abstract: The current study aims to develop a methodology for obtaining topology-optimal structures made of short fiber-reinforced polymers. Each iteration of topology optimization involves two consecutive steps: the first is a simulation of the injection molding process for obtaining the fiber orientation tensor, and the second is a structural analysis with anisotropic material properties. Accounting for the molding process during the internal iterations of topology optimization makes it possible to enhance the weight efficiency of structures—a crucial aspect, especially in aerospace. Anisotropy is considered through the fiber orientation tensor, which is modeled by solving the plastic molding equations for non-Newtonian fluids and then introduced as a variable in the stiffness matrix during the structural analysis. Structural analysis using a linear anisotropic material model was employed within the topology optimization. For verification, a non-linear elasto-plastic material model was used based on an exponential-and-linear hardening law. The evaluation of weight efficiency in structures composed of short-reinforced composite materials using a dimensionless criterion is addressed. Experimental verification was performed to confirm the validity of the developed methodology. The evidence illustrates that considering anisotropy leads to stiffer structures, and structural elements should be oriented in the direction of maximal stiffness. The load-carrying factor is expressed in terms of failure criteria. The presented multidisciplinary methodology can be used to improve the quality of the design of structures made of short fiber-reinforced composites (SFRC), where high stiffness, high strength, and minimum mass are the primary required structural characteristics.

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Analysis of Effectiveness of Combined Surface Treatment Methods for Structural Parts with Holes to Enhance Their Fatigue Life

Authors: Olexander Grebenikov, Andrii Humennyi, Serhii Svitlychnyi, Vasyl Lohinov and Valerii Matviienko

Abstract: The typical and most widespread stress concentrators in the lower wing panels of aircraft are the drain holes located on the stringer vertical ribs. These are prime sources for the initiation and development of fatigue cracks, which lead to early failure of the wing structure. Therefore, improving fatigue life in these critical areas is one of the significant issues for research. Two combined methods of surface plastic treatment in the location around drain holes are discussed in this paper. Using the finite element method and ANSYS software, we created a finite element model and obtained nonlinear solution results in the case of tension in a plate with three holes. In addition, the development of residual stress due to the surface plastic treatment of the hole-adjacent areas was taken into account. In this paper, it is shown that after surface treatment of the corresponding areas of the holes, residual stress, which exceeds the yield stress for the plate material, is induced. When combined with alternative tensile stress, these reduce the amplitude of the local stresses, thus increasing the number of stress cycles before failure. The benefits of this technology were confirmed by fatigue test results, which include the fatigue failure types of the plates. Graphs showing the impact of applicable surface treatment combined methods on the number of cycles to failure were also plotted.

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Computational Fracture Modeling for Effects of Healed Crack Length and Interfacial Cohesive Properties in Self-Healing Concrete Using XFEM and Cohesive Surface Technique

Authors: John Hanna and Ahmed Elamin

Abstract: Healing patterns are a critical issue that influence the fracture mechanism of self-healing concrete (SHC) structures. Partial healing cracks could happen even during the normal operating conditions of the structure, such as sustainable applied loads or quick crack spreading. In this paper, the effects of two main factors that control healing patterns, the healed crack length and the interfacial cohesive properties between the solidified healing agent and the cracked surfaces on the load carrying capacity and the fracture mechanism of healed SHC samples, are computationally investigated. The proposed computational modeling framework is based on the extended finite element method (XFEM) and cohesive surface (CS) technique to model the fracture and debonding mechanism of 2D healed SHC samples under a uniaxial tensile test. The interfacial cohesive properties and the healed crack length have significant effects on the load carrying capacity, the crack initiation, the propagation, and the debonding potential of the solidified healing agent from the concrete matrix. The higher their values, the higher the load carrying capacity. The solidified healing agent will be debonded from the concrete matrix when the interfacial cohesive properties are less than 25% of the fracture properties of the solidified healing agent.

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